CHAPTER 5

MANUFACTURING OF NANO-HYBRID COMPOSITES
CYLINDER LINER (NL)

5.1 INTRODUCTION

In order to verify and establish the suitability of the newly developed nano-hybrid composite materials for application as cylinder liner in diesel engines, the liner is manufactured to be fitted in an engine and tested. This chapter presents the step-by-step procedure adopted in the manufacture of the new NL. Four liners were fabricated using the newly developed composite containing 6.75% by weight of the combined reinforcements.

5.2 NL MANUFACTURING AND MACHINING

For the fabrication of the composite liner, the required quantity of ceramic reinforcements and solid lubricant at micro-size and Al6061 matrix materials were purchased. The particle size of ZrO₂ ceramic reinforcement was kept under 100 nm size through ball-milling process. A controlled bottom pouring stir casting machine was used to make new NLs through sand mould route. Particulate nano-hybrid reinforced Al6061 composites could be processed more easily by liquid state processes.

Controlled bottom pouring stir cast arrangement helps to regulate the molten metal flow to the NL molten box. The mold was allowed to cool in atmospheric air for approximately 8 hours. Casting and machining allowances were considered during manufacturing process to achieve the dimensions of the new NL to be the same as those of the CL shown in Figure 5.1. The predominant load on the liner is thermal stresses. Owing to the better frictional characteristics of the newly developed NL material, the frictional losses will be lesser than that
in the existing CL. Further, the thermal expansion of the new liner material is nearly one-fourth that of lesser than that of cast iron. Hence, the stresses induced will be much lesser in the new NL. Hence, the dimensions of the new NL were maintained to be the same as those of the CL shown in Figure 5.1. This helped to avoid the changes of the internal, external and other related engine components structure. Casting and machining allowances were considered during manufacturing process of NL. It was machined using computer numerical control (CNC) procedure and finished through honing operation, and the new NLs were obtained, as shown in Figure 5.2. To minimize the manufacturing uncertainties, four NLs (NL1, NL2, NL3, and NL4) were manufactured using the same procedure, and the same dimensions were maintained the same as that of the original CL.

Figure 5.1. Specification of NL
The weights of the new NLs were measured using a three-digit accuracy measuring scale, which showed approximately 44% saving compared to the currently used CL as shown in Table 5.1. The variations in the weights of the NL were found to be negligible with a maximum deviation of 0.25%. Although all four fabricated liners were ready to use, NL2 had 1.1% greater weight than the other three lightweight composite liners, indicating that complete bonding of reinforcements with matrix was achieved during manufacturing.
process. A light weight is an important parameter for vehicles fuel consumption and complete bonding are important parameters for nano-hybrid composite manufacturing, all the manufactured NLs has almost 1.800 kgf which was 43.75% lighter than the weight of the present CL which is 3.2 kgf.

Table 5.1 Comparison of weights

<table>
<thead>
<tr>
<th>Name of the liner</th>
<th>Weight (kgf)</th>
<th>% of weight-saving compared to CL liner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present CL</td>
<td>3.200</td>
<td>--</td>
</tr>
<tr>
<td>New NL 1</td>
<td>1.791</td>
<td>44.0</td>
</tr>
<tr>
<td>New NL 2</td>
<td>1.800</td>
<td>43.7</td>
</tr>
<tr>
<td>New NL 3</td>
<td>1.792</td>
<td>44.0</td>
</tr>
<tr>
<td>New NL 4</td>
<td>1.794</td>
<td>43.9</td>
</tr>
</tbody>
</table>

5.4 THEORETICAL AND EXPERIMENTAL VERIFICATION OF NL DENSITY

The density of the proposed NLs was estimated using RoHm. To verify the same, the density of the developed NLs was experimentally measured through Archimedes’ principle (Kumar et al. 2010). The results are shown in Figure 5.3. The mean difference between theoretical and experimental density values of all the four manufactured NL liners was 1.7%. Density of nano-hybrid composite materials has a stronger impact on thermal conductivity (Ling et al. 2014) and other properties. So, the new nano-hybrid liner 2 (NL2) was selected for conducting further studies in a single-cylinder diesel engine.
Figure 5.3 Comparison of theoretical and experimental density values of fabricated NLs

5.5 SUMMARY

The nano-hybrid composite material with combined reinforcement of 6.75% by weight with Al6061 matrix material was used to manufacture a NL through bottom pouring stir casting process. It was machined by CNC machine and finished by honing process to have the same dimensions as the original CL. The next chapter presents the details of the performance of CL and the developed NL in a single cylinder diesel engine.